CHAPTER 4

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CHAPTER 6

A HEURISTIC PROGRAM FOR ASSEMBLY LINE BALANCING

1960 Award Winner

THE FORD FOUNDATION DOCTORAL DISSERTATION SERIES

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Carnegie Institute of Technology

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A HEURISTIC PROGRAM FOR ASSEMBLY LINE BALANCING

FRED M. TONGE

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To my wife

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Foreword

This volume is one of five doctoral dissertations selected for publication in the second annual Doctoral Dissertation Competition sponsored by the Program in Economic Development and Administration of The Ford Foundation. The winning dissertations were completed during the academic year 1959–60 by doctoral candidates in business administration, in the social sciences and other fields relevant to the study of problems of business.

The dissertation competition is intended to generalize standards of excellence in research on business by graduate students. It should give widespread professional recognition to persons recently awarded doctorates in business whose dissertation research is especially distinguished by its analytical content and strong roots in underlying disciplines. It is also intended to give recognition to a selected number of persons outside business schools who in their doctoral dissertations pursued with distinction interests relevant to the field of business.

The dissertations selected include, in addition to Dr. Tonge's monograph:

Decentralization of Authority in a Bureaucracy
Bernard H. Baum
Department of Sociology
University of Chicago

The Distribution of Automobiles:
An Economic Analysis of a Franchise System
Bedros Peter Pashigian
Department of Economics
Massachusetts Institute of Technology

The Choice of Wage Comparisons
Martin Patchen
Department of Social Psychology
University of Michigan

Marketing in an Underdeveloped Economy: The North Indian Sugar Industry
Leon V. Hirsch
Graduate School of Business Administration
Harvard University

In the first year of the competition four of the five dissertations selected made extensive use of mathematical and statistical tools. This may have led some to the mistaken impression that mathematically-oriented dissertations are unduly favored in the selection process. The results of the second year's competition should serve to correct any such misapprehension. Four of the five dissertations published this year are largely non-mathematical, thus underscoring our conviction that many disciplines, including mathematics, can make important contributions to rigorous business research.

On behalf of The Ford Foundation, I wish to express my gratitude to the Editorial Committee for the care and thought its members devoted to the selection process. The same scholars who served on the Committee for the first year's competition gave us the benefit of their experience by serving a second year. They are: Professors Robert Ferber of the University of Illinois, Sherman J. Maisel of the University of California (Berkeley), and William Foote Whyte of Cornell University.

As in the first year, the Editorial Committee's task was considerably lightened by the assistance of ten readers, experts in the wide range of disciplines covered in the Competition, who carefully screened each of the dissertations submitted. The Foundation joins the Committee in acknowledging their debt to Professors Austin C. Hoggatt, Julius Margolis and Lyman W. Porter of the University of California (Berkeley), Richard M. Cyert of the Carnegie Institute of Technology, Harry V. Roberts of the University of Chicago, Frank Miller and Henry Landsberger of Cornell University, Myron J. Gordon of the Massachusetts Institute of Technology, Samuel Goldberg of Oberlin College, and Robert B. Fetter of Yale University, for serving as readers in the second year of the competition.

Finally, my colleagues and I wish to acknowledge the substantial contribution of Prentice-Hall, Inc., to the publication and distribution of the selected dissertations.

Thomas H. Carroll
Vice President
The Ford Foundation

New York, New York
December, 1960

Preface

This volume reports a heuristic program for assembly line balancing. By assembly line balancing we mean the process of assigning jobs to workers stationed along a continuous assembly line. Our goal has not been to develop an optimum procedure for this assignment, but rather to develop an acceptable procedure using certain new problem-solving techniques. These techniques concern both specification of a problem-solving procedure and implementation of that procedure on a digital computer. We have studied assembly line balancing both as an interesting problem in its own right and as representative of a large number of industrial problems to which these techniques have potential application.

Many industrial decisions entail selecting some optimum combination of factors from a space of many possible combinations. Assembly line balancing, job shop scheduling, personnel and equipment assignment are examples of this class of combinatorial problems. Mechanization of solution procedures for such problems can (potentially) contribute not only dollar savings through better solutions for the cost, but also intangible returns through much quicker results. A purpose of this research is to explore one approach to such mechanization.

Because no general theory exists for dealing with large scale combinatorial problems, much basic mathematical research in this area has been directed toward developing computational shortcuts and approximations for treating such problems [see, for example, Dantzig, Fulkerson, and Johnson (7) or Bryton (4)]. In fact, the combinatorial problems listed above are members of the class of ill-structured problems [Simon and Newell (32)]—known exhaustive algorithms for their solution require too much computational effort to be feasible.

The work of Newell, Shaw, and Simon (23) on heuristic problem-solving, although oriented toward human cognitive process rather than industrial decisions, suggests both an approach to combinatorial problems using heuristic procedures and a method of employing electronic computers to carry out these procedures. The research reported here aims to extend these techniques to the solution of the assembly line balancing problem.

Our two goals are: 1. to develop an acceptable, though not necessarily optimum, procedure for assembly balancing, 2. to gain some understanding of the use of computers for implementing heuristic decision procedures in the industrial management area.

The organization of this paper reflects these two goals. The first two chapters provide background information to the assembly line balancing problem. In Chapter 1 we define the line balancing problem in its more general setting of the assembly operation as a whole. In Chapter 2 we view assembly line balancing as a combinatorial problem, examining both general considerations of combinatorial problems and other approaches to the assembly line balancing problem.

Chapters 3 and 4 summarize our assembly line balancing procedure as it presently exists, Chapter 3 describing the procedure and Chapter 4 the results obtained in applying it to several test problems. In Chapter 5 we examine the procedure within a more general framework for problem-solving.

Chapter 6 concerns the philosophy of this approach to using digital computers in dealing with ill-structured problems, drawing upon examples from the line balancing program to illustrate the realization of this approach. In Chapter 7 we present conclusions and extensions of the research to related areas.

The Appendices contain a complete presentation of the actual sample problems used (Appendix A) and the protocols produced by the problem-solving procedure (Appendix B). We also include descriptions in English of the detailed heuristics employed (Appendix C) and of the representation of data within the computer (Appendix D).

The research reported here arose from joint exposure to the assembly line balancing problem in its industrial setting and to the work of Newell, Shaw, and Simon on heuristic programming.

This work has been supported to varying degrees by the Graduate School of Industrial Administration, Carnegie Institute of Technology, an IBM Fellowship, The RAND Corporation, and the Westinghouse Electric Corporation.

Although many people have contributed to developing this topic, the author particularly acknowledges the stimulation and encouragement of A. Newell, J. C. Shaw, and H. Kanter of The RAND Corporation, and H. A. Simon of Carnegie Institute of Technology.

Mrs. Jessie Hausner and Miss Margie Knight provided expert secretarial assistance.

Of course, sole responsibility for content lies with the author.

FRED M. TONGE

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